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CLASSROOM METHODS AND DEVICES

Science for Prevocational Boys

The major purpose of the work in science for prevocational boys is not to turn out scientists capable of doing elaborate scientific work, but to create a rudimentary interest in scientific facts and principles; to call attention to and explain the more obvious and simple phenomena which the boys meet in their daily surroundings; to lead the pupils to see that science means the substitution of real knowledge for mere guesswork—the development of rational procedure in the place of the antiquated rule of thumb; to give an idea of the important part which the development of scientific knowledge has played in our modern industrial progress; and to give practice in reasoning and in applying some of the principles of science.

A secondary but important purpose of giving the so-called science work to these children is to utilize their interest in scientific phenomena as a basis for English composition, spelling, drawing, and mathematics. It is believed that the work in science can be organized in such a way as to furnish this correlating principle.

Since only a limited amount of time can be devoted to science, and since the purpose of giving it is slightly different from that which is usually urged for high-school science, for example, it is desirable to note the way in which the subject is presented, especially as the laboratory method is not employed. In defense of the method which is described in the following paragraphs, it may be said that as only four hours a week are devoted to the subject, this brief period would be rather unproductive if divided between laboratory work and classroom instruction. If the time were devoted entirely to laboratory work it is doubtful whether any more would be accomplished. Even if we grant that a few more scientific facts and principles could be learned through laboratory work, the loss incurred by the employment of the proposed method is more than compensated for by the gain in the pupils' ability to interpret the printed page and to express themselves in writing and in drawing, and, moreover, the work in the shops provides considerable concrete information of a scientific nature. This makes the demand for laboratory work in science less imperative.

A method which has been found successful is to have the pupils study a general science textbook and other supplementary material, and make notebooks which, when completed, constitute illustrated textbooks covering almost the entire work given in the subject. Demonstrations are given by the teacher to arouse interest and to make the work concrete. They are such as can be performed with relatively little apparatus, or at least with such equipment as can be used in an ordinary classroom.

The textbooks are used as reference books and for the purpose of supplementing information given by the teacher during the demonstrations. Multiple copies of direct questions based on the text and on the demonstrations are prepared and each pupil is supplied with a copy. The nature of these questions will be seen from typical illustrations which appear below.

The usual classroom procedure is to begin with the demonstration and to follow this by the reading of the texts and by notebook work guided by the question sheets. When there is no demonstration, the teacher makes an assignment in which he tries to arouse a desire on the part of the pupils to study the text. This is followed by recitation work in which the pupils answer orally the questions on the question sheet. During these oral recitations the slower pupils have an opportunity to profit from the recitations of the brighter ones, and the difficult parts of the text are cleared up for all. Then the lesson is concluded by notebook work.

At this point the character of the question sheets, upon which the notebook work is based, must be described. At first the questions follow the text rather closely and are designed to aid the pupil in mastering the text by focusing his attention on the main thoughts. These questions are so worded as to encourage the pupil to use his own vocabulary rather than the words found in the text. Often they break up the thought of a long and rather involved sentence into several shorter sentences, thus enabling the pupil to get the meaning of the paragraph which was obscured by the long sentence. Often a question is so worded that its answer involves giving the thought of a whole paragraph. In the early part of the work subordinate questions are placed under these major questions, to assist the pupil in formulating a logical and intelligent answer.

A typical question of the latter kind is the following, which is based upon a paragraph describing how a Fahrenheit thermometer is graduated. The main question and its subordinates follow:

Q. (*a*) How is a Fahrenheit thermometer graduated?
A. Begin: A thermometer is graduated in the following way: Then answer the following:
  (*b*) How is the 212° mark found?
  (*c*) How is the 32° mark found?
  (*d*) How many degrees are there then between the 32 mark and the 212° mark?
  (*e*) Now if we want each space between the melting point of ice and the boiling point of water to represent two degrees, how many spaces will there be between the 32° mark and the 212° mark?
  (*f*) How long, then, will each space be?
  (*g*) How is this length of space made use of?

As the pupils improve in their ability to write in better form, and reach the point where they can dispense with the subordinate questions, the questions follow the text less closely, become less specific and particular in character, and involve the composition of several related sentences, comprising a paragraph. Toward the end of the year's work, outlines are prepared from which the pupils write shorter or longer compositions on scientific subjects.

Correlation between science and drawing is secured by so wording a question that it calls for graphic expression in connection with the answer. Mathematics is correlated with the science by inserting among the questions problems concerning levers, the inclined plane, pulleys, the differential pulley, the wheel and axle, the screw, the lifting jack, gears, the bicycle, the geared windlass, etc. These problems involve the use of the processes of addition, multiplication, division, and subtraction of whole numbers and especially of common fractions and decimals.

Practice in reasoning is afforded by inserting questions and exercises which call for the application of principles found in the text. As a rule the answers to questions of this type are not found in the book. The following are samples of the exercises of this kind: If you were a track foreman on a railroad, what directions would you give your gang for laying rails in the winter? Why? If you were a lineman for a telephone company, how would you string the wires in summer? Why? How does the boiler-maker take advantage of contraction due to cooling when he rivets boiler plates together?

In some cases, instead of following the above method, the inductive development lesson precedes the study of the text.

While the pupils are studying the texts and answering the questions, the instructor has an opportunity to give individual instruction on points which are not made entirely clear in the demonstration, or which the pupils find obscure in the text. He has also the opportunity of calling attention to mistakes in spelling, sentence structure, punctuation, and erroneous answers; and to make suggestions in regard to figures which the pupils draw.

One feature of the instruction which it is believed accounts largely for its success, and which should be characteristic of all prevocational work, is that the boys are continually encouraged when they show the least interest, accomplishment, or improvement in their work, and are almost never told that they are doing poor or worthless work. Instead they are shown by example how they can improve, and are given the commendation they deserve.

A word must be said in regard to the motivation of the notebook work. In order that ownership of the texts by the boys may not remove the motive for making the notebooks, all the reference books are furnished by the University. The sources of information are numerous enough to prevent the boys from coming to the conclusion that the notebook work could be made unnecessary through the purchase of a textbook. Furthermore, the fact is pointed out that each boy will in reality be compiling a book for himself which will contain information drawn from many sources, the purchase of which would involve considerable expense. Some emphasis is laid on the fact that an attempt will be made to put into the notebooks only the most valuable information, the less valuable and too technical being disregarded. Special emphasis is laid on the fact that the boys have an opportunity to create something which will be of value to them; which they may exhibit with pride to their parents, if they choose to make it creditable; which will be representative of the work of the class and which, in case of a school exhibit, may be shown with considerable credit to themselves and the class.

Several encouraging results have been obtained. First, there is an added interest in reading about scientific facts, and an added ability to learn facts from the printed page. Second, there is an acquisition of a few fundamental and useful facts. Third, the work develops an interest in, and to some extent an understanding of, the scientific features of industrial processes many of which can be illustrated in the shop work. Fourth, there is acquired by the pupil added ability to express himself in writing and drawing. Fifth, the observation of the simple rules of punctuation and capitalization tends to become habitual, and the pupils become more efficient in the fundamental operations of arithmetic. Sixth, the boys frequently acquire a keen zest in writing and rewriting their notebooks, some of which finally reach a point of genuine excellence.

The following illustrative material is planned to show in a concrete way how a given topic is treated; for example, heat. Under this general heading are given, among others, the following:

Introduction.
General Effects of Heat.
Expansion and Contraction.
Uses of Expansion and Contraction.
Methods of Heating Buildings.
Ventilation.
Methods of Transmitting Heat.
Measuring Heat.
Sources of Heat.

The following questions are selected from a total of 98 questions covering this general topic and are illustrative of the principles which have been described above.

HEAT

A. INTRODUCTION

1. Show how heat and fire do damage every day.
2. Tell how heat is used for good purposes.

B. GENERAL EFFECTS OF HEAT

1. Expansion and Contraction.
   - *a*) Tell how you could prove that heat makes water expand.
     - (1) First tell what things you would use.
     - (2) Then tell how you would use them.
   - *b*) How could you show that heat makes air expand?
   - *c*) Make up an experiment to show that heat causes expansion.
     - (1) Tell first what materials you would use.
     - (2) Then tell how you would use them.
   - *d*) How do you think things act when they are cooled?
   - *e*) What in general may we say is the general effect of heat and cold?
2. Exceptions. Heat does not always cause expansion.
   - *a*) Does ice for example expand or contract when heated?
   - *b*) How does water act when cooled from 39 Fahrenheit to 32?
   - *c*) Are there any metals that contract when heated?

C. USES OF EXPANSION AND CONTRACTION

1. How does the blacksmith make use of heat to make iron expand?
2. How does he make use of the contraction due to cooling?
3. How do boiler-makers make use of contraction due to cooling?
4. If you were track foreman on a railroad, what directions would you give for laying the rails in winter? Why?
5. How would you order them to be laid in summer? Why?
6. If you were lineman for a telephone company, how would you string wires in summer? Why?
7. What causes cement walks to hump and crack in summer?
8. How could this be prevented?

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E. METHODS OF HEATING BUILDINGS

1. In early times before stoves were invented, how were buildings heated?
2. Explain why smoke goes up the chimney.
3. Why is the open fireplace a healthful way of heating?
4. In what respect was the stove an advance over the fireplace as a means of heating?
5. What part is played by the draft or inlet of a stove?
6. What harm is done by having the damper of the stove wide open all the time?
7. Which is the better way of heating a building: by stoves or by a hot-air furnace? Give two reasons why you think as you do.
8. Explain by means of a diagram how a hot-air furnace works.
9. Explain by means of a diagram how the hot-water heating system works?
   - *a*) What would you say led to the invention of hot-water heating systems?

- *b*) Draw a diagram of a two-room house with a hot-water boiler in the basement and explain how the water circulates.
- *c*) How does the hot water in the radiators heat the rooms?
- *d*) What does a hot-air furnace do that a hot-water heating system does not do?
- *e*) How is ventilation provided for in connection with some hot-water heating systems?
- *f*) Why is ventilation necessary?
- *g*) In what respects are hot-water systems better than hot-air furnaces?

10. The steam-heating system.
    - *a*) Draw the cross-section of a two-room house which is heated by steam and explain how system works.
    - *b*) What device is used to prevent boilers from blowing up? Show how it works.
    - *c*) In what respects is heating by steam better than heating by hot water?
    - *d*) On the other hand what advantages has hot water over steam heating?
11. Make a short summary on the three ways of heating.

Begin: We may summarize on the three ways of heating by saying (*a*) First, give the advantages of the hot-air furnace. (*b*) Then give the disadvantages of the same. (*c*) Third, give the good points of heating by hot water. (*d*) Then tell its weak points. (*e*) Close with a statement of which system you prefer.

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G. METHODS OF TRANSMITTING HEAT

1. Convection.
   - *a*) Define convection.
   - *b*) How does the Gulf Stream illustrate the transference of heat by convection?
   - *c*) Give two more examples of heat transferred by convection.

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2. Conduction.
   - *a*) Define conduction.
   - *b*) Give two examples of heating by conduction.
   - *c*) Define good and poor conduction of heat.
   - *d*) Show how poor conductors of heat are made use of.
   - *e*) Show how good conductors are made use of.
3. The fireless cooker.
   - *a*) Explain the construction of the fireless cooker. (Draw diagram.)
   - *b*) Upon what principle did its invention depend?
4. Radiation.
   - *a*) Explain radiation of heat.
5. Describe the processes which take place when rooms are heated by steam.

H. MEASURING HEAT

1. Show that while the temperature of a body tells how hot the body is, it does not tell the amount of heat in the body.
2. Tell how heat is measured.
   - *a*) The calorie.
   - *b*) Calculation of number of calories.
   - *c*) The British thermal unit.
   - *d*) Calculation of number of B.T.U.'s.
3. Specific heat.
   - *a*) Introduction.
   - *b*) Definition.
   - *c*) What does the specific heat of a substance tell you?
   - *d*) Give several examples to make this clear.

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